# PART I - ADMINISTRATIVE

## Section 1. General administrative information

**Title of project**

N A T U R E S [Formerly Supplemental Fish Quality (Yakima)]

**BPA project number:** 9105500
**Contract renewal date (mm/yyyy):** 3/1999 ☐ **Multiple actions?**

**Business name of agency, institution or organization requesting funding**
National Marine Fisheries Service

**Business acronym (if appropriate)** NMFS

**Proposal contact person or principal investigator:**


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**NPPC Program Measure Number(s) which this project addresses**
7.2D.1, 7.2D.2 and 7.2D.3

**FWS/NMFS Biological Opinion Number(s) which this project addresses**

**Other planning document references**
NMFS ESA Snake River Salmon Recovery Plan Section 4.4.c and 4.4.d

**Short description**
Develop and evaluate fish culture techniques (seminatural raceway habitat, predator avoidance training, exercise, live food diets, etc.) for a natural rearing enhancement system that increases the postrelease survival of artificially propogated salmon.

**Target species**
chinook salmon, sockeye salmon, coho salmon, and steelhead trout

## Section 2. Sorting and evaluation

**Subbasin**
Systemwide

### *Evaluation Process Sort*

| CBFWA caucus | Special evaluation process | ISRP project type |
|---|---|---|
| Mark one or more caucus | If your project fits either of these processes, mark one or both | Mark one or more categories |
| ☒ Anadromous fish<br>☐ Resident fish<br>☐ Wildlife | ☒ Multi-year (milestone-based evaluation)<br>☐ Watershed project evaluation | ☐ Watershed councils/model watersheds<br>☐ Information dissemination<br>☐ Operation & maintenance<br>☐ New construction<br>☒ Research & monitoring<br>☐ Implementation & management<br>☐ Wildlife habitat acquisitions |

## Section 3. Relationships to other Bonneville projects

***Umbrella / sub-proposal relationships.*** List umbrella project first.

| Project # | Project title/description |
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### *Other dependent or critically-related projects*

| Project # | Project title/description | Nature of relationship |
|---|---|---|
| 9701300 | Yakima Cle Elum Hatchery O & M | Strategies being developed under NATURES are being implemented in YKFP test of supplementation. |
| 833500 | Nez Perce Tribal Hatchery O & M | Strategies being developed under NATURES will be used in the Nez Perce fish culture facilities |
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## Section 4. Objectives, tasks and schedules

### *Past accomplishments*

| Year | Accomplishment | Met biological objectives? |
|---|---|---|
| 1992 | Completed Literature Review. | Yes-developed NATURES concepts. |

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| 1992 | On a laboratory scale demonstrated that full term rearing of fall chinook salmon in seminatural raceway habitat increases instream postrelease survival. | Yes-demonstrated seminatural raceway habitat increases survival. |
| 1994 | On a laboratory scale demonstrated that acclimation rearing of spring chinook salmon in seminatural raceway habitat increases instream postrelease survival. | Yes-demonstrated seminatural raceway habitat increases survival. |
| 1994 | On a pilot scale demonstrated that full term rearing of fall chinook salmon in seminatural raceway habitat increases instream postrelease survival. | Yes-demonstrated seminatural raceway habitat increases survival. |
| 1997 | Completed design and physical evaluation of seminatural raceway habitat using resin rock pavers for production scale raceways. | Yes-demonstrated resin rock pavers, camouflage net covers, and conifer instream structure is suitable for production scale fish culture operations. |
| 1998 | On a production scale demonstrated that full term rearing of fall chinook salmon in seminatural raceway habitat with resin rock paver substrate increases instream survival. | Yes-demonstrated seminatural raceway habitat increases instream survival. |
| 1995 | Completed design and physical evaluation of automatic subsurface feed delivery system. | Yes-demonstrated a mechanically effective automated subsurface feed delivery system. |
| 1995 | On a pilot scale demonstrated that automatic subsurface feed delivery systems do not affect fall chinook salmon behavior. | Yes-determined automated subsurface feed delivery systems do not affect depth preference, vulnerability to predators, or response to objects near surface. |
| 1992 | With laboratory trials demonstrated that live food supplemented diets improve fall chinook salmon foraging success. | Yes-demonstrated live food supplemented diets improve foraging ability. |
| 1997 | With field trials demonstrated live food diets improve fall chinook salmon foraging success. | Yes-demonstrated live food diets improve foraging abiltiy. |
| 1998 | Completed design of an oval exercise system that can be retrofitted to production raceways to exercise fish in a cost-effective manner. | Yes-demonstrated that fish can be exercised by modifying existing raceways. |
| 1997 | Demonstrated chinook salmon instream postrelease survival is increased by being exposed to a diverse array of live predators during culture pilot scale raceways. | Yes-demonstrated predator avoidance training increases survival. |
| 1997 | Demonstrated chinook salmon can be | Yes-demonstrated predator |

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| | conditioned to respond to the scent of a predator. | avoidance conditioning may be possible with scent alone. |
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### ***Objectives and tasks***

| Obj 1,2,3 | Objective | Task a,b,c | Task |
|---|---|---|---|
| 1 | Determine if rearing salmon in seminatural raceway habitat increases postrelease survival. | a | Develop raceway habitats composed of natural substrate, instream structure, and overhead cover. |
| | | b | Use pilot scale evaluations to determine how these seminatural raceway components affect salmon behavior, coloration, growth, disease status, predator vulnerability, and instream postrelease survival. |
| | | c | Based on these pilot scale evaluations, select a workable seminatural raceway habitat with the greatest promise of producing wild-like fish with increased smolt-adult survival. |
| | | d | Conduct production scale evaluation at salmon enhancement hatcheries to verify the selected seminatural raceway habitat increases smolt-adult survival. |
| 2 | Determine if rearing salmon in raceways where food is presented in a natural manner by underwater feeders increases postrelease survival. | a | Develop underwater feeding system. |
| | | b | Use pilot scale evaluations to determine how underwater feed delivery systems affect salmon behavior, growth, disease status, predator vulnerability and instream postrelease survival. |
| | | c | Based on these pilot scale evaluations, select a workable underwater feed delivery system with the greatest promise of producing wild-like fish with increased smolt-adult survival. |
| | | d | Conduct production scale evaluation |

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| | | | at salmon enhancement hatcheries to verify the selected underwater feed delivery system increases smolt-adult survival. |
| 3 | Determine if predator avoidance training increases postrelease survival. | a | Develop predator avoidance training protocols. |
| | | b | Use pilot scale evaluations to determine how these predator avoidance training protocols affect salmon behavior, growth, disease status, predator vulnerability, and instream postrelease survival. |
| | | c | Based on these pilot scale evaluations, select a predator avoidance training protocol with the greatest promise of producing wild-like fish with increased smolt-adult survival. |
| | | d | Conduct production scale evaluations at salmon hatcheries to verify the selected predator avoidance training protocol increases smolt-adult survival. |
| 4 | Determine if rearing salmon in raceways with natural current velocities that exercise fish increases postrelease survival. | a | Develop technology to increase the water velocity in raceways to at least one body length per second. |
| | | b | Using this technology, develop exercise protocols. |
| | | c | Use pilot scale evaluations to determine how these exercise protocols affect salmon behavior, morphology, growth, pathology, predator vulnerabilty, and instream postrelease survival. |
| | | d | Based on these pilot scale evaluations, select a workable exercise protocol with the greatest promise of producing wild-like fish with increased smolt-adult survival. |
| | | e | Conduct production scale evaluations at salmon enhancement hatcheries to verify the selected exercise protocol increases smolt-adult-survival. |

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| 5 | Determine if rearing salmon on diets supplemented with natural live feeds increases postrelease survival. | a | Develop live food diets. |
| | | b | Use pilot scale evaluations to determine how these live food diets affect salmon behavior, foraging ability, coloration, growth, disease status, predator vulnerability, and instream postrelease survival. |
| | | c | Based on these pilot scale evaluations, select the live food diet with the greatest promise of producing wild-like fish with increased smolt-adult survival. |
| | | d | Conduct production scale evaluation at salmon hatcheries to verify the selected live food diet increases smolt-adult survival. |
| 6 | Determine if rearing salmon in raceways with natural sound levels increases salmon postrelease survival. | a | Develop quieting technology that can be retrofitted to hatcheries so that fish can be reared in raceways with natural acoustic levels. |
| | | b | Use pilot scale evaluations to determine how rearing in natural and artificially noisy acoustic levels affects salmon behavior, morphology, growth, pathology, predator vulnerability, and instream postrelease survival. |
| | | c | If the pilot scale evaluations indicate problems with unnatural noise levels, conduct production scale evaluation at salmon hatcheries to verify that quieting hatcheries to natural acoustic volumes increases smolt-adult survival. |
| 7 | Determine if rearing salmon in raceways with full oxygen saturation throughout the raceway increases postrelease survival. | a | Use pilot scale evaluations to determine how rearing salmon in full oxygen saturation levels effects salmon behavior, morphology, growth, pathology, predator vulnerabilty, and instream postrelease survival. |
| | | b | If the pilot scale evaluations indicate problems with unnaturally low |

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| | | | oxygen levels, then conduct production scale evaluation at salmon hatcheries to verify that maintaining oxygen at saturation levels increases smolt-adult survival. |
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### *Objective schedules and costs*

| Obj # | Start date mm/yyyy | End date mm/yyyy | Measureable biological objective(s) | Milestone | FY2000 Cost % |
|---|---|---|---|---|---|
| 1 | 8/1991 | 12/2005 | yes | X | 40.00% |
| 2 | 3/1994 | 10/1996 | yes | X | 7.50% |
| 3 | 8/1991 | 8/2005 | yes | X | 10.00% |
| 4 | 3/1991 | 12/2005 | yes | X | 10.00% |
| 5 | 8/1991 | 10/1998 | yes | X | 12.50% |
| 6 | 1/2000 | 1/2006 | yes | X | 15.00% |
| 7 | 1/2000 | 1/2006 | yes | X | 5.00% |
| | | | | **Total** | 100.00% |

**Schedule constraints**
The schedule may be modified when new ideas offering solutions to problems arise. The main constraint that may cause schedule changes is the level of funding and the accessability of production scale facilities to evaluate smolt-adult survival.

**Completion date**
2006

## Section 5. Budget

**FY99 project budget (BPA obligated):** $500,000

### *FY2000 budget by line item*

| Item | Note | % of total | FY2000 |
|---|---|---|---|
| Personnel | | %31 | 154,000 |
| Fringe benefits | | %6 | 28,000 |
| Supplies, materials, non-expendable property | | %12 | 60,600 |
| Operations & maintenance | | %6 | 28,000 |

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| Capital acquisitions or improvements (e.g. land, buildings, major equip.) | | %11 | 57,000 |
| NEPA costs | | %0 | 0 |
| Construction-related support | | %0 | 0 |
| PIT tags | # of tags: 6000 | %3 | 17,400 |
| Travel | | %4 | 18,000 |
| Indirect costs | | %11 | 54,000 |
| Subcontractor | PSMFC contractual services | %17 | 83,000 |
| Other | | %0 | 0 |
| **TOTAL BPA FY2000 BUDGET REQUEST** | | | $500,000 |

### *Cost sharing*

| **Organization** | **Item or service provided** | **% total project cost (incl. BPA)** | **Amount ($)** |
|---|---|---|---|
| NMFS | Personnel, Equipment, Supplies, and O & M | %34 | 255,000 |
| | | %0 | |
| | | %0 | |
| | | %0 | |
| **Total project cost (including BPA portion)** | | | $755,000 |

### *Outyear costs*

| | **FY2001** | **FY02** | **FY03** | **FY04** |
|---|---|---|---|---|
| **Total budget** | $500,000 | $500,000 | $600,000 | $600,000 |

## Section 6. References


| **Watershed?** | **Reference** |
|---|---|
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# PART II - NARRATIVE

## Section 7. Abstract

The project's goal is to develop a Natural Rearing Enhancement System (NATURES) that enables hatcheries to produce wild-like salmon with increased postrelease survival. Conservation and supplementation programs can use NATURES-reared salmonids to rapidly rebuild stocks that are currently listed as endangered and threatened into healthy self-sustaining runs. Traditional production programs can use high survival NATURES-reared fish to reduce their impact on wild populations, while still meeting their adult mitigation goals. The project's primary objectives are to determine if seminatural raceway habitats, exercise current velocities, automated underwater feeders, live food supplemented diets, predator avoidance training, oxygen supplementation, and sound (acoustic noise) reduction can be used by fish culturists to produce wild-like fish with increased postrelease survival. The development of these techniques to produce wild-like hatchery fish with improved postrelease survival is called for in sections 7.2D.1, 7.2D.2, and 7.2D.3 of the Columbia Basin Fish and Wildlife Program and sections 4.4.c and 4.4.d of the ESA Snake River Salmon Recovery Plan.

The basic method the program uses to reach each objective is to: 1) develop fish rearing protocols, 2) evaluate each protocol on a pilot scale to determine if it produces wild-like salmon with increased instream survival, 3) refine and reevaluate the protocols, 4) select the best protocol, and 5) evaluate its effect on smolt-adult survival with production scale releases. At every stage of the research the project incorporates the scientific method of strong inference for solving problems, compares experimental treatment fish to

conventionally reared controls, incorporates testable null hypotheses that can be refuted, and uses statistical analysis in decision making.

This evaluation process generally takes less than 3 years to prove that a protocol increases instream survival. An additional 4 years or more is then required to prove that the technique also increases smolt-adult survival. The sooner evaluations are begun, the more rapidly solutions to the postrelease survival problems experienced by hatchery salmon can be found.

The project has developed several fish culture practices that produce wild-like fish with a 25-50% higher instream survival than conventionally reared salmon. When these techniques are incorporated into production releases, they should translate into increased smolt-adult survival. The natural rearing enhancement system will enable supplementation and conservation hatcheries to produce wild-like salmon with high postrelease survival that can be used to rapidly rebuild naturally spawning runs. This project will help return a productive fishery to the river and conserve the salmonid resources of the Columbia River Basin.

## Section 8. Project description

### a. Technical and/or scientific background

The Resource Enhancement and Utilization Technology Division (REUT), National Marine Fisheries Service (NMFS), in collaboration with the Washington Department of Fish and Wildlife (WDFW), and US Fish and Wildlife Service (USFWS) has been conducting research to develop a natural rearing enhancement system (NATURES) suitable for producing “wild-like” fish with high postrelease survival from hatcheries. NATURES research has provided rearing criteria for salmonids that will be used in Yakima and Nez Perce Fisheries Projects tests of supplementation. NATURES research is crucial to the restoration of many depleted stocks within the Snake River Basin (e.g., those listed under the U.S. Endangered Species Act). Development of natural rearing systems that minimize behavioral changes in hatchery-reared fish is identified as a priority [4.4.c and 4.4.d] in the proposed Recovery Plan for Snake River salmon. The development of fish culture techniques to increase the survival of Columbia River hatchery salmonids is called for in sections 7.2D.1. 7.2D.2, and 7.2D.3 of the Columbia Basin Fish and Wildlife Program.

We reviewed the literature to determine how salmonid biology is altered by fish culture practices (Maynard et al. 1995, Maynard et al. 1996 a, b, and c). The postrelease survival of hatchery-reared fish is often considerably lower than that of wild-reared fish (Greene 1952, Miller 1952, Salo and Bayliff 1958, Reimers 1963). This reduced survival may stem from how the behavior and morphology of hatchery- and wild-reared salmon differs. Unlike wild fish, hatchery-reared fish appear to be inefficient foragers in their natural environment, whose stomachs are empty or filled with indigestible debris (Miller 1953, Hochackka 1961, Reimers 1963, Sosiak et al. 1979, Myers 1980, O’Grady 1983, Johnsen and Ugedal 1986). The two rearing types also have markedly different social behavior, with hatchery-reared fish congregating at higher densities, being more aggressive, and displaying less territory fidelity than wild-reared salmonids (Fenderson et al. 1968, Bachman 1984, Swain and Riddell 1990). In the natural environment, these differences result in hatchery-reared fish spending more time in high risk aggressive behavior and less time in beneficial foraging behavior than their wild-reared counterparts. Hatchery-reared fish are often more surface oriented than wild fish (Mason et al. 1967, Sosiak 1978). They also have a brighter coloration than wild reared fish and are less competent at swimming in natural stream velocities. These characteristics may make them more vulnerable to predators. Although some of these differences between wild and hatchery-reared fish are innate (Reisenbichler and McIntyre 1977, Swain and Riddell 1990), many are conditioned, and can be modified by altering the hatchery rearing environment.

Traditionally, salmon are reared at unnaturally high densities in barren light gray raceways. This artificial environment lacks camouflage-inducing substrates, refuge-providing instream structure, shade-generating overhead cover, and exercise-promoting stream velocities. The fish are conditioned to approach large moving objects that spread artificial feeds over the water surface. This conventional approach has increased the egg-to-smolt survival of hatchery-reared fish by an order of magnitude over that experienced by wild-reared salmon. However the behavioral, physiological, and morphological characteristics hatchery-reared fish develop in this environment significantly reduces their smolt-adult survival compared to wild-reared salmon.

The literature was reviewed with the aim of developing salmon culture techniques that increase survival to adulthood by rearing salmon in a less artificial environment. This review suggests that rearing salmon in a stream-like environment with natural substrates, instream structure, and overhead cover might produce fish with higher postrelease survival because their color patterns blend into the backgrounds of the streams and river where they are released (Donnelly and Whoriskey 1991, Maynard et al. 1995, Maynard et al. 1996 a and b). It also proposes that hatchery salmonids might be trained to recognize and avoid the predators they may encounter after release (Thompson 1966, Kanayama 1968, Olla and Davis 1989, Maynard et al. 1998b). In other species, supplementing standard pellet diets with live feeds increases foraging success and may increase the postrelease survival of hatchery-reared Pacific salmon (Johnson 1978, Hesthagen and Johnsen 1989, Maynard et al. 1996b). The surface orientation of hatchery-reared fish might be corrected by use of automatic subsurface feed delivery systems that condition fish to retain their natural benthic orientation and innate response to moving objects. The literature suggests that exercising Pacific salmon by providing stream-like current velocities in raceways should increase stamina and might improve their postrelease migratory and predator evasion abilities (Christiansen et al. 1989, Christiansen and Jobling 1990, Christiansen et al. 1992, Besner and Smith 1983, Schurov et al. 1986a, Schurov et al. 1986b, Cresswell and Williams 1983, Burrows 1969, Wendt and Saunders 1972, and Leon 1986). Numerous papers indicate that reducing rearing density would markedly improve smolt-adult survival (Martin and Wertheimer 1989, Hopley 1980, Fagerlund et al. 1987, Denton 1988, Downey et al. 1988, Banks 1990). Preliminary sound recordings and research on nonsalmonid fish suggest that reducing artificial noise in hatcheries to stream background levels may prevent auditory damage and improve survival. The literature on oxygen supplementation suggests that increasing dissolved oxygen levels to saturation or higher throughout raceways may improve survival to adulthood (see Maynard et al. 1995 for review).

The information from this literature review was incorporated into the design of a NATURES rearing system with the potential to produce "wild-quality" fish with higher postrelease survival than conventional hatchery-reared salmon. These NATURES strategies included: 1) rearing salmon in raceways equipped with cover, structure, and natural substrates that promote the development of natural camouflage coloration; 2) automated underwater feed delivery systems that condition fish to orient to the bottom rather than the surface; 3) training fish to avoid predators; 4) exercising fish to enhance their ability to escape predators; 5) feeding salmon live food diets to improve their foraging ability; 6) reducing rearing densities; and 7) utilizing oxygen supplementation technology to improve fish health and physiology. These NATURES strategies should enable hatcheries to produce “wild-like” fish that are better suited for use in supplementation programs than conventionally-reared fish. These NATURES strategies should also help minimize the potential genetic divergence between wild and hatchery-reared salmon.

Evaluations of the effect of NATURES rearing strategies on hatchery salmon postrelease survival have been underway since 1992. Each evaluation begins with laboratory scale studies that tests and refines the proposed concept until it is proven to produce fish with the desired morphological, physiological, and behavioral attributes. Successful concepts are then run through pilot scale evaluations to verify that they increase instream postrelease survival and can be operated at production facilities. Those concepts that can be adapted to production scale facilities and produce large increases in instream survival are then evaluated with production releases from state and federal hatcheries to determine their effect on smolt-adult survival.

The NATURES project has successfully tested the seminatural raceway habitat and predator avoidance training concepts through the pilot scale stage. These concepts have increased chinook salmon (*Oncorhynchus tshawytscha*) instream survival by 20-50% (Maynard et al. 1996c, Maynard et al. 1998 a and b). Production scale research is now underway to determine the effect of seminatural raceway habitat on the smolt-adult survival of chinook salmon. NATURES laboratory studies have also demonstrated that live food diets can be used to improve the foraging success of chinook salmon (Maynard et al. 1996b). However, further investigation of this concept is on hold until it can be shown that the foraging benefits generated by these diets outweigh the economic costs of their implementation at production hatcheries. Pilot scale evaluations indicate that subsurface feed delivery systems do not induce more benthic orientation or reduce the predator vulnerability of chinook salmon (Maynard et al. unpublished). This research has been set aside until new ideas on how feed delivery systems may be used to increase postrelease survival can be generated. Laboratory scale research has developed technology that generates economically feasible exercise velocities in rectangular (raceway) vessels. Research is now being conducted to determine if exercise increases the instream survival of chinook salmon.

At the project's conclusion, a complete Natural Rearing Enhancement system will have been developed that produces salmon which are behaviorally, physiologically, and morphologically similar to their wild-reared counterparts. These NATURES salmon will have a high postrelease survival and should be genetically similar to the wild stocks from which they were derived. NATURES rearing protocols will provide supplementation and conservation programs with the type of hatchery-reared salmon needed to rapidly rebuild endangered and threatened runs of Pacific Northwest Salmon. They will provide salmon enhancement programs with the high survival fish needed to restore fisheries to the Columbia River Basin.

## b. Rationale and significance to Regional Programs

Research, development, and testing of new fish culture techniques, like NATURES, with the objective of improving survival to adulthood are called for in several sections of the CBFW program. In section 7.2D.1 it is requested that "Research, development, and demonstration of improved husbandry practices at hatchery, which will lead to increased production and improved fish survival to adulthood" be conducted. In section 7.2D.3 it is requested that "Research, development and testing of hatchery rearing operation and release strategies to increase the survival of artificially propagated fish to adulthood" be conducted. In addition Section 7.2D.2 calls for "an evaluation to determine whether high levels of sound at hatcheries has an adverse effect on the survival of hatchery fish".

The Proposed NMFS Recovery Plan for Snake River Salmon also calls for the development of NATURES rearing strategies that "improve the survival of Columbia River Basin anadromous salmonids by improving the quality of fish released from hatcheries"(Section 4.4). Section 4.4.c of the plan calls for testing rearing strategies "incorporating shade, substrate, cover, structure, etc. in rearing containers and developing procedures for fish training in predator evasion foraging, and other postrelease survival skills". Section 4.4.d specifically requests that "NMFS, FWS, BPA, and NBS should develop new, natural rearing systems that minimize behavioral changes in hatchery-reared fish".

Innovative hatchery practices, like NATURES, that produce wild-like fish with high survival are crucial to ensuring that hatcheries can be successfully used to rapidly rebuild endangered and threatened salmon runs within the Columbia River Basin. The wild-like characteristics produced by NATURES rearing, being similar to characteristics that have been shaped by generations of natural selection, offer hatchery-reared salmon the best chance for survival when they are released back into the natural environment. In addition, a naturalistic hatchery environment that produces salmon with wild-like behavior, physiology, and morphology should be less selective for domestic traits than the conventional hatchery environment. NATURES strategies, like seminatural raceway habitat, predator recognition training, and exercise, will enable hatcheries to produce better camouflaged salmonids, with appropriate antipredator responses, that are more physically fit to escape from predators. NATURES salmonids that are reared on live-food supplemented diets and exercised will be better at recognizing, pursuing, and capturing prey than conventional hatchery-reared salmonids. The high postrelease survival of NATURES reared fish will: 1) reduce the number of wild broodstock that must be taken into fish culture programs to produce a given number of recruits in the next generation, 2) reduce the time required for supplementation programs to rebuild self-sustaining runs, and 3) enhance the efficiency of mitigation and fishery enhancement hatchery programs.

NATURES researchers have assisted the Biospecification Work Group (Yakima) and Natures Design Team (Nez Perce) in incorporating NATURES rearing strategies into both the Yakima and Nez Perce Fisheries Projects tests of supplementation [Yakima Fishery Project EIS (DOE/EIS-0169) and Nez Perce Tribal Hatchery Program EIS(DOE/EIS-0213)]. NATURES staff scientists frequently advise Federal, tribal, state, Public Utility District, and regional fisheries enhancement groups on how NATURES fish culture techniques can best be incorporated into their hatchery programs. These efforts have resulted in IDFG, ODFW, WDFW, and USFWS salmon culture facilities also testing NATURES rearing protocols to determine if they increase survival to adulthood.

## c. Relationships to other projects

While serving on the Biospecifications Work Group, NATURES scientists helped develop the experimental rearing variables for the Yakima Fisheries Project test of supplementation. As members of the NATURES Design Team, NATURES researchers provided advice on how to incorporate NATURES concepts into the salmon culture facilities to be used in the Nez Perce test of supplementation. Both ODFW and IDFG scientists investigating the effect of seminatural raceway habitat on fish survival at Lookinglass and Sawtooth hatcheries have consulted with NATURES researchers. NATURES scientists are currently working with WDFW and LLTK on a production scale evaluation of how seminatural raceway habitat affects chinook salmon survival to adulthood. This work, which is being conducted at Forks Creek Hatchery on the Willapa River is jointly funded by the NFWF, NMFS, and Weyerhaeuser Corporation. In addition, NATURES staff scientists frequently advise Federal, tribal, state, PUD, and regional fisheries enhancement groups on how NATURES fish culture techniques can be incorporated into their fish culture programs. As a result of these activities, NATURES fish culture protocols are beginning to be adopted at fish culture facilities.

## d. **Project history** (for ongoing projects)

*Project numbers:* 910500

*Project reports and technical papers:*

Berejikian, B. A., E.P. Tezak, T. A. Flagg, R. J. F. Smith, S. L. Schroder, and C. M. Knudsen. 1998. Chemical alarm signaling in chinook salmon smolts: an opportunity for anti-predator conditioning. p. 63-67. In Proceedings of the Forty-Eighth Northwest Fish Culture Conference, December 2-4, 1997 Gleneden Beach, Oregon.

Maynard, D. J., T. A. Flagg, and C. V.W. Mahnken. 1995. A review of seminatural culture strategies for enhancing the post-release survival of anadromous salmonids. American Fisheries Society Symposium 15:307-314.

Maynard, D. J., G. C. McDowell, E. P. Tezak, and T. A. Flagg. 1996. The effect of diets supplemented with live-food on the foraging behavior of cultured fall chinook salmon. Progressive Fish-Culturist 58:187-191.

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken, and S. L. Schroder. 1996. Natural rearing technologies for increasing postrelease survival of hatchery-reared salmon. Bulletin National Research Institute of Aquaculture, Supplement 2:71-77.

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken. 1996. Development of a natural rearing system to improve supplemental fish quality. Annual Report 1991-1995. DE-A179-91BP20651, Bonneville Power Administration, Portland, Oregon.

Maynard, D. J., T. A. Flagg, C. V. W. Mahnken and S. L. Schroder. 1998. Natural Rearing Enhancement System Technology for Salmon Culture. p. 45-50 In Proceedings of the Columbia River Anadromous Salmonid Rehabilitiation and Passage Symposium. E. L. Brannon and W. C. Kinsel editors Aquaculture Research Institute, University of Idaho, Moscow.

Maynard, D. J., E. P. Tezak, M. Crewson, D. A. Frost, T. A. Flagg, S. L. Schroder, C. Johnson, and C. V. W. Mahnken. 1998. Seminatural raceway habitat increases chinook salmon post-release survival. p. 81-91. In Proceedings of the Forty-Eighth Northwest Fish Culture Conference, December 2-4, 1997 Gleneden Beach, Oregon.

Maynard, D. J., A. L. LaRae, G. C. McDowell, G. A. Snell, T. A. Flagg, and C.V.W. Mahnken. 1998. Predator avoidance training can increase post-release survival of chinook salmon. p. 59-62. In Proceedings of the Forty-Eighth Northwest Fish Culture Conference, December 2-4, 1997 Gleneden Beach, Oregon.

*Summary of major results achieved:*

A literature review of the differences between wild and hatchery-reared salmonids and possible fish culture solutions for improving the survival of hatchery-reared salmonids has been completed (Maynard et al. 1995, Maynard et al. 1996 a, b, and c). Several NATURES fish culture strategies for producing more adept fish with increased instream survival have been developed.

The increase in postrelease survival that benefits chinook salmon by being reared in seminatural raceway habitat has been demonstrated from the laboratory to production scale. The instream survival of fall chinook salmon reared full term in 400-L tanks fitted with overhead cover, plastic aquarium plant structure, and gravel substrates was 51% higher than fish reared in standard barren raceway environments (Maynard et al. 1998 a and b). This experiment was then repeated with spring chinook salmon using an acclimation approach where the fish were reared in the seminatural habitat for only the last four months prior to release. Under clear water release conditions, the instream survival of seminaturally reared fish was 24% higher than conventionally reared salmon (Maynard et al. 1998b). The research was then elevated to a pilot scale in 5,947-L raceways. The fish reared in vessels with camouflage net cover, conifer instream structure, and gravel substrates averaged a 27% higher instream survival than conventionally reared salmon (Maynard et al. 1998b). In these pilot scale raceways the camouflage net covers and conifer instream structure did not pose a maintenance problem, however loose gravel presented same severe cleaning problems in small tanks. This problem was solved with the development of a resin rock paver that provided the benefits of natural substrate, without the maintenance problem associated with loose gravel. A production scale test measuring the effect of seminatural raceway habitat on smolt-adult survival is now underway with fall chinook salmon reared in 25,374-L raceways. The instream survival of seminaturally reared fish has averaged 10% higher than that of conventionally reared fish in this test. In all these experiments seminaturally reared fish have a darker coloration that blends into the natural background of streams, rivers, and estuaries better than the light coloration of conventionally reared fish (Maynard et al. 1998b).

Two NATURES studies have demonstrated that live food diets improve the foraging success of hatchery-reared salmon. In laboratory tests, fall chinook salmon reared on a live food supplemented diet consumed twice as many live prey as fish reared on pellets alone (Maynard et al. 1996b). In field trials where fish were challenged to forage for a week in riverine enclosures, fall chinook salmon reared on live food diets had twice as much edible material in their gut as their counterparts reared on pellets alone (Maynard et al. unpublished). We recommend that further investigation into the economical production of live food diets be conducted before this research is carried to pilot scale.

NATURES research indicates that predator avoidance training can be used to increase postrelease survival. Chinook salmon have been shown to rapidly learn to recognize and avoid predators in the laboratory (Olla et al. 1996). Laboratory research suggests predator avoidance conditioning may only require fish to be exposed to the chemical cues associated with predator and injured prey (Berijikian et al. 1998). NATURES field work has demonstrated that training fall chinook salmon to avoid a combination of live predators (hooded mergansers *Lophodytes cucullatus*, largemouth bass *Micropterus salmoides*, and brown bullhead *Ictalurus nebulosus*) they will encounter after release increases instream survival by 26% (Maynard et al. 1998c). However, predator avoidance training requires further refinement before being taken to production scale tests as not all conditioning protocols have been successful.

NATURES researchers have developed an oval design that can be easily retrofitted to production scale raceways to achieve exercise velocities. Tests in laboratory troughs with fall chinook salmon demonstrate that exercise velocities of 0.75 to 1.25 ft/sec can be achieved in an energetically efficient manner with the oval design. Research is currently underway to determine optimal exercise protocols and their effect on postrelease survival.

*Adaptive management implications*:

The goal of supplementation and conservation programs for threatened and endangered stocks is to develop methods to enhance populations by supplementing wild stocks with hatchery fish. The use of hatchery fish to supplement native populations holds good potential for recovery of natural populations, but existing techniques are controversial. NATURES research is a critical step in determining how live food diets, automated subsurface feeders, and seminatural rearing habitat may increase the postrelease survival of hatchery salmonids. Predation experiments will also help to demonstrate whether predation is a significant factor in the differential postrelease survival of test fish. These studies will help to define rearing environment factors critical to improving postrelease survival of fish released for supplementation.

The knowledge gained from our past activities has allowed us to focus on and refine those experimental variables that contribute most to enhancing the post-release survival of hatchery-reared salmonids. Based on our research findings, we recommend that hatchery-reared fish used to supplement, restore, or enhance natural populations be reared in seminatural environments with substrate, instream structure, and overhead cover. Based on these findings, we conclude that future research should focus on: 1) determining the best form of each seminatural habitat component (e.g., pea gravel vs. resin encased rock substrate), 2) determining if the increased instream survival benefits of seminatural habitat rearing translate into increased fishery and spawner returns and, 3) developing and evaluating other prerelease conditioning techniques (predator avoidance training, exercise, etc.) for further enhancing hatchery-reared salmon postrelease survival.

*Years underway*: Six years (1991-1998)

*Past costs:* FY 1993 - $472,000; FY 1994 -$0; FY 1995 - $400,000; FY 1996 -$372,000, FY 1997 - $399,200, FY 1998-399,500.

## e. Proposal objectives

All the null hypotheses generated by the objectives can be directly tested and do not require that any assumptions be made. The objectives and their associated testable hypotheses are as follows:

1. Determine if rearing salmon in seminatural raceway habitat increases postrelease survival. Ho: Rearing salmon in seminatural raceway habitat does not increase postrelease survival. Ha: Rearing salmon in seminatural raceway habitat increases postrelease survival.
2. Determine if rearing salmon in raceways where food is presented in a natural manner by underwater feeders increases postrelease survival. Ho: Rearing salmon in raceways where food is presented in a natural manner by underwater feeders does not increase postrelease survival. Ha: Rearing salmon in raceways where food is presented in a natural manner by underwater feeders increases postrelease survival.
3. Determine if predator avoidance training increases salmon postrelease survival. Ho: Predator avoidance training does not increase salmon postrelease survival. Ha: Predator avoidance training increases salmon postrelease survival.

4. Determine if rearing salmon in raceways with natural current velocities that exercise fish increases postrelease survival. Ho: Rearing salmon in raceways with natural current velocities that exercise fish does not increase postrelease survival. Ha: Rearing salmon in raceways with natural current velocities that exercise fish does increase postrelease survival.
5. Determine if rearing salmon on diets supplemented with natural live feeds increases postrelease survival. Ho: Rearing salmon on diets supplemented with natural live feeds does not increase postrelease survival. Ha: Rearing salmon on diets supplemented with natural live feeds increases postrelease survival.
6. Determine if unnaturally high sound levels in hatchery incubation and rearing vessels decrease postrelease survival. Ho: Exposing salmon to unnaturally high sound levels during incubation and rearing does not decrease postrelease survial. Ha: Exposing salmon to unaturally high souund levels during incubation and rearing does decrease postrelease survival.
7. Determine if rearing salmon in full oxygen saturated water increases postrelease survival. Ho: Rearing salmon in full oxygen saturated water does not increase postrelease survival. Ha: Rearing salmon in full oxygen saturated water does increase postrelease survival.

The project's primary products are experimental findings that are published in annual reports and peer reviewed scientific publications. These findings are also presented at workshops and scientific meetings. In conducting the research, chinook salmon that are produced for experimental purposes are also released into the Columbia River Basin. The project's most valuable products are the new fish culture practices it has developed to increase salmon instream survival by 20-50%.

## f. Methods

Research in FY 2000 will continue to evaluate and refine NATURES components (seminatural raceway habitat, subsurface automated feeders, predator avoidance training, exercise current velocities, live food supplemented diets, natural sound levels, and oxygen supplementation) described under objectives 1-7. It is expected that the work will focus on: 1) verifying that seminatural raceway habitat increases smolt-adult survival (task 1d); 2) refining predator avoidance training protocols with predation bioassays, instream releases, and if the protocol is sufficiently refined in 1999 initiating a smolt-adult survival evaluation in FY 2000 (tasks 3a-d); 3) refining exercise protocols with predation bioassays and instream survival releases (tasks 4a-d); 4) refining live food supplemented diets and evaluating their effect on postrelease survival (tasks 5a-b); 5) continuing research begun in 1998 examining the ecological interactions between conventionally-, NATURES-, and wild-reared fish; and 6) initiating a new line of research determining how unnatural levels of sound affect predator vulnerability and instream survival (tasks 6a-c). The general methodology used in these studies has been fully described in Maynard et al. (1996a). This methodology is modified as appropriate to fit the specific location and stock of fish being studied.

The research associated with all five objectives follows the same overall plan. First, the literature is reviewed to develop new fish culture techniques that can be used to increase postrelease survival. Laboratory and pilot scale evaluations are then used to determine how the experimental techniques affect growth, inculture survival, behavior, fish health, predator vulnerability and instream survival. These evaluations are continued until the proposed rearing technique is either fully refined or is recommended for elimination from the program because it cannot be made to work as proposed. The fully refined techniques are then evaluated on a production scale at salmon hatcheries to determine how they affect smolt-adult survival. Those techniques that increase smolt-adult survival are recommended for incorporation into the natural rearing enhancement system.

In all experiments, the fish are reared in replicated groups with no less than three groups per treatment. Both control and experimental treatment fish are reared following standard fish culture methods. The only difference in how the control and experimental treatment fish are reared is the specific NATURES protocol that the experiment is testing. The experimental treatment in these studies has been and may include overhead cover, natural substrate, instream structure, subsurface feed delivery systems, exercise current velocities, predator avoidance training protocols, and live food diets. Fish rearing is usually conducted in rectangular raceway-like vessels that are about 400 liters in size in laboratory scale evaluations, 6,000 liters in size in pilot scale evaluations, and more than 25,000 liters in size in production scale hatchery evaluations of smolt-adult survival. Most studies will use a full term rearing approach with the fish reared in the experimental treatments from swimup until they smolt. However, some experiments will use an acclimation approach with the experimental rearing treatments applied only during the last few months of experimental rearing.

Inculture evaluations include comparing the growth performance of fish in the control and experimental treatments by measuring their fork length and weight at 4-week intervals. Fish health is examined by maintaining mortality logs and removing a representative sample (n = 30 fish/treatment) and performing a fish health profile at the end of rearing. In studies evaluating seminatural raceway habitat a representative sample of fish (n = 30) is removed from both treatments for colormetric sampling. Where appropriate, the behavior of fish during rearing is observed and the social, aggressive, foraging, and depth distribution patterns of the fish in the control and experimental treatments compared with appropriate parametric and nonparametric statistics.

In some evaluations, predation and postrelease foraging bioassays are performed prior to the fish being released. In predation bioassays a representative sample (n = 20 fish/treatment) is removed from both treatments and placed in the predation test arena. Predators are allowed to fish in the arena until half the salmon have been eaten. This procedure is repeated at least 15 times and then the ratio of fish surviving/preyed upon for the two treatments is compared with contingency table analysis. Foraging bioassays involve placing a single fish in a laboratory test arena or an insitu cage and challenging it to forage on available prey. This procedure is repeated at least 40 times using 20 fish from each treatment. The foraging behavior data collected during these bioassays is analyzed with nonparametric Mann-Whitney U tests. The stomach weight data of the two treatments is compared with parametric t-tests.

In all the NATURES studies, the effect of the rearing treatments on postrelease survival is the bottom line. The relatively fast turn around time between fish release and data recovery results in juvenile instream survival tests being the best tool for refining the rearing treatments. In these evaluations, a representative sample of 1,500 fish from each treatment is tagged. The fish are then allowed to recover from the effects of tagging, before they are trucked to an upstream release site, where they are released and challenged to successfully survive migration to a downstream weir. The ratio of fish recovered/unrecovered from the treatments is compared with a contingency table analysis. Depending on the number of treatments, the travel time to the weir is compared with t-test or ANOVA. NATURES instream survival evaluations have been conducted in a number of watersheds including the Yakima River, Little Anderson Creek, Big Beef Creek, Bingham Creek, Curley Creek, and Ollala Creek.

When a rearing protocol has been fully refined and shown to be workable, smolt-adult survival evaluations are initiated. In these evaluations the control and experimental treatment fish are grown in side by side vessels at a production scale hatchery. At least a month before release, the fish are coded wire tagged so that their smolt-adult survival can be compared using tag recoveries from the fishery, spawning ground surveys, and hatchery returns. The number of fish tagged per treatment, number of rearing vessels per treatment, and number of years fish are released depends on the expected tag return rate, hatchery, and stock of fish. A study currently underway with fall chinook salmon incorporates 33,000 fish per raceway, three raceways per treatment, and plans to conduct experimental releases for a four year period. The smolt-adult survival of the rearing treatments will be compared with a contingency table analysis. The size of recovered fish will be compared with a t-test or ANOVA depending on the number of treatments and release years. These smolt-adult survival evaluations are the acid test used to determine if NATURES rearing protocols increase survival sufficiently to justify their full scale implementation within the Columbia River Basin. NATURES smolt-adult survival evaluations are currently being conducted with chinook salmon in the Willapa and the Snake River Basins.

The sample size chosen for these postrelease survival evaluations is based on being able to detect at least a 20% difference between rearing treatments. In most cases the laboratory and instream survival releases can detect much smaller differences between treatments. The statistical tests selected are based on the type of data collected and its distribution.

The goal of supplementation and conservation programs for threatened and endangered stocks is to develop methods to enhance populations by supplementing wild stocks with hatchery fish. The use of hatchery fish to supplement native populations holds good potential for recovery of natural populations, but existing techniques are controversial. NATURES research is a critical step in determining how live food diets, automated subsurface feeders, and seminatural raceway habitat, predator avoidance training, and exercise can be used to increase the postrelease survival of hatchery salmonids. Seminatural raceway habitat and predator avoidance training rearing strategies allow hatchery programs to increase the instream survival of their fish by 25-50%. It is expected these techniques will provide similar increases in survival to adulthood. It is expected that with further refinement live food diets will increase survival to adulthood as they have foraging success in the laboratory and field enclosures. Exercising should improve the migratory abilities, predator evasion, and ultimately postrelease survival of hatchery-reared fish. Work done with Fundulus indicates that sound dampening hatcheries may increase both inculture as well as postrelease survival. The increased survival offered by these NATURES fish culture techniques will allow supplementation and conservation hatcheries to rapidly restore self-sustaining natural runs in areas where salmon are now threatened, endangered, or extinct.

It is expected the NATURES project will provide conservation, supplementation, and enhancement hatcheries with fish culture techniques enabling them to produce wild-like salmon with high postrelease survival. These fish can then be used to rapidly rebuild the Columbia River's diminishing salmon runs. This will help return a productive fishery to the river and conserve the Columbia Basin's salmonid resources. Implementation of NATURES strategies will allow Columbia River salmon populations to recover to self sustaining and harvestable levels. NATURES rearing strategies may also result in hatchery-reared fish retaining more of the adaptive traits found in the wild populations from which they were sourced.

There are no special animal care or environmental protection requirements. There are also no special risks to habitats, other organisms, or humans.

### g. Facilities and equipment

The research is conducted at the NMFS Manchester Marine Laboratory freshwater rearing facilities, State hatcheries, and USFWS hatcheries. Experimental rearing at Manchester is conducted in six 6,000-L rectangular raceways and twenty 1,152-L rectangular troughs. The facility is supplied with 440 gpm of pumped surface water from Beaver Creek. Alarms and backup generators are used to ensure an uninterrupted flow of life support water to experimental fish. Emergency oxygen is also available to sustain fish in an emergency. Project fish that are reared at state and federal production facilities are supported with all the standard equipment and backup systems required to ensure fish safety and quality.

The Manchester Laboratory is equipped with predator bioassay test arenas, a fish behavior building containing two 12-m long simulated streams, and a 40-m long simulated river channel. The laboratory has all professional grade balances, microscopes, hoods, and reagents required to monitor inculture fish performance and health. Two field portable video systems and portable computers equipped with event recording software are available for studying fish behavior. Insulated transport tanks and two 1-ton four wheel drive trucks are available for fish transport. Each year the laboratory places weirs on Kitsap County creeks (e.g., Curley Creek and Ollala Creek) so that they can be used to conduct instream survival evaluations. The laboratory has the skilled personnel and equipment to tag and mark fish with most standard methods (freeze brand, PIT-tags, photonic tags, coded wire tags, etc.).

The Manchester laboratory is equipped with computers and software to statistically analyze data, write reports, and produce journal publications. A machine shop and specialized construction equipment including cranes, tractors, backhoes, welding equipment, plumbing equipment, and electrician tools are available on site at the Laboratory. This equipment is used in fabricating NATURES environments, predator training cages, insitu foraging cages, weirs, and other specialized research equipment as needed.

**h. Budget**

The personnel and fringe benefit budget covers about 30% of the salary of the administration (1), principal investigator (3), biologist (1), and technician (1) staff assigned to the NATURES project. Additional biological (2), technical (1), and research mechanic (1) staff are assigned to the project through the grant (listed under subcontract) to the PSMFC. The supplies, materials, and nonexpendable property budget includes all the feeds, medications, pathology supplies, fish culture supplies, behavioral supplies, event recorder software, statistical analysis software, report writing and presentation software, computers, cameras, film, film developing, image processing software, video equipment for observation, materials for fabrication of specialized NATURES fish culture systems, exercise pumps, weir fabrication materials, water loss alarm systems, emergency oxygen equipment, plumbing materials used for fish culture, electrical equipment used in fish culture, construction materials used in fish culture, construction material used in research, and construction materials used to retrofit raceways at production hatcheries. The operation and maintenance budget includes the electrical pumping costs associated with NATURES fish culture, city well water used for research, and telephone costs associated with carrying out the research. The capital acquisitions or improvements budget includes the cost of purchasing and installing raceways, troughs, and other vessels used in the research. The project uses 6,000 PIT-tags each year in the instream survival evaluations. The travel budget primarily covers vehicles and the cost of investigator travel to field sites to collect data. It also covers the cost of presentation of project research at international, national, and regional scientific meetings and program reviews.

## Section 9. Key personnel

1. Mr. Thomas A. Flagg, Fisheries Research Biologist. Co-principle Investigator @ 25% FTE. Duties include internal project oversight; research; external project coordination; data analysis and report writing; etc. [See attached resume for qualifications.]

2. Dr. Desmond J. Maynard, Fisheries Research Bioligist: Co-principle Investigator @ 100% FTE. Duties include internal project oversight; research; external project coordination; data analysis and report writing; etc. [See attached resume for qualifications.]

3. Dr. Barry A. Berejikian ,Fisheries Research Bioligist: Co-principle Investigator @ 50% FTE. Duties include internal project oversight; research; external project coordination; data analysis and report writing; etc. [See attached resume for qualifications.]

CURRICULUM VITAE--**Thomas A. Flagg**

**Education:** B.S. (Fisheries Biology), University of Washington, Seattle, WA; 1976.
M.S. (Fisheries Biology), University of Washington, Seattle, WA; 1981.

**Employer:** National Marine Fisheries Service, Northwest Fisheries Science Center, Resource Enhancement & Utilization Technology Division.

**Position:** Fisheries Research Biologist, NMFS employee since 1978.

**Present assignment:** Team Leader, Salmon Enhancement Projects. Responsibilities include: development of fish husbandry technology to produce wild-type juvenile salmon for release from hatcheries; development of supplementation techniques for restoration of depleted stocks of salmonids to their native habitats; and development of captive broodstock programs to conserve depleted gene pools of salmonids.

**Previous research/expertise:** Includes research associated with: determination of status of depleted stocks of fish including those proposed for listing as threatened or endangered under the Endangered Species Act; development of the passive integrated transponder (PIT) tagging system for salmonids; development of freshwater and seawater net-pen aquaculture husbandry and captive broodstock techniques for Atlantic and Pacific salmon (including research in the areas of aquaculture systems design and development, stock rearing strategies, nutrition, disease investigations, maturation and spawning, hormonal sex reversal, smoltification, and stock performance); investigation of fish-collection and transportation related mortalities in juvenile salmonids in the Columbia River system; evaluation of the impact of the 1980 Mt. St. Helens eruption on juvenile salmonids in the Columbia River system; and investigation of the relationship between swimming behavior, smoltification status, and seawater survival for coho salmon.

Relevant Publications include:

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken, and S. L. Schroder. 1996. Natural rearing technologies for increasing postrelease survival of hatchery-reared salmon. Bull Natl. Res. Inst. Aquacult., Suppl. 2:71-77.

Maynard, D. J., G. C. McDowell, E. P. Tezak, and T. A. Flagg. 1996. The effect of diets supplemented with live-food on the foraging behavior of cultured fall chinook salmon. Prog. Fish-Cult. 58:187-191.

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken (editors). 1996. Development of a natural rearing system to improve supplemental fish quality. Report to the Bonneville Power Administration, Contract DE-A179-91BP20651, 216 p. (Available Northwest Fisheries Science Center., 2725 Montlake Blvd. E., Seattle, WA 98112.)

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken. 1995. A review of semi-natural culture strategies for enhancing the postrelease survival of anadromous salmonids. American Fisheries Society Symposium 15:307-314.

Mahnken, C. V. W., G. Ruggerone, W. Waknitz, and T. A. Flagg. 1998. A historical perspective on salmonid production from Pacific Rim Hatcheries. N. Pac. Anadr. Fish. Comm. Bull. No. 1:38-53.

CURRICULUM VITAE--**Dr**. **Desmond J. Maynard**

**Education:**

A.A., Business management, Cape Cod Community College, Hyannis, MA, 1971.
B.S., Marine Biology, University of Massachusetts, North Dartmouth, MA, 1974.
M.S., Fisheries Science, University of Washington, Seattle, WA, 1980.
Ph.D., Fisheries Science, University of Washington, Seattle, WA, 1987.

**Employer:** National Marine Fisheries Service, Northwest Fisheries Science Center, Resource Enhancement & Utilization Technology Division.

**Position:** Fisheries Research Biologist, NMFS employee since 1988.

**Present assignment:** Principal investigator on the NATURES project. Dr. Maynard's responsibilities include developing NATURES protocols, designing experiments to evaluate the effect of these protocols on postrelease survival, oversight of daily experimental activities, analyzing data, preparing the study finding for publication in annual reports and journal articles. The research he has conducted on the project has demonstrated that seminatural raceway habitat increases instream survival, live food supplemented diets improve foraging ability, and predator avoidance conditioning improves postrelease survival.

**Previous research/expertise:** Dr. Maynard's primary expertise is in fish behavior and culture. He has taught graduate level courses on fish sociobiology and behavioral ecology, conducted research on the social behavior of salmon, and investigated the effects of petroleum on salmon homing and migration. Dr. Maynard has been a member of the Animal Behavior Society since 1977, where he has served on the applied animal behavior and film committees. He has taught college level courses on Aquaculture and his research since 1992 has focused on developing culture techniques to increase the postrelease survival of hatchery salmon. Dr. Maynard also has expertise in fish taxonomy and evolution and has been a member of the NMFS Biological Review Teams for several petitioned listings. He also has expertise in fish tagging having led several investigations comparing the effects of tags on fish survival.

Relevant Publications include:

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken, and S. L. Schroder. 1996. Natural rearing technologies for increasing postrelease survival of hatchery-reared salmon. Bull Natl. Res. Inst. Aquacult., Suppl. 2:71-77.

Maynard, D. J., G. C. McDowell, E. P. Tezak, and T. A. Flagg. 1996. The effect of diets supplemented with live-food on the foraging behavior of cultured fall chinook salmon. Prog. Fish-Cult. 58:187-191.

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken (editors). 1996. Development of a natural rearing system to improve supplemental fish quality. Report to the Bonneville

Power Administration, Contract DE-A179-91BP20651, 216 p. (Available Northwest Fisheries Science Center., 2725 Montlake Blvd. E., Seattle, WA 98112.)

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken. 1995. A review of semi-natural culture strategies for enhancing the postrelease survival of anadromous salmonids. American Fisheries Society Symposium 15:307-314.

CURRICULUM VITAE-- **Dr. Barry A. Berejikian**

**Education:**

B.S., Fisheries Science, California Polytechnic State University, San Luis Obispo, CA., 1990.
M.S., Fisheries Science, University of Washington, Seattle, WA, 1992.
Ph.D, Fisheries Science, University of Washington, Seattle, WA, 1995.

**Employer:** National Marine Fisheries Service, Northwest Fisheries Science Center, Resource Enhancement & Utilization Technology Division.

**Position:** Fisheries Research Biologist, NMFS employee since 1994.

**Present assignment:** Principal investigator on the NATURES project. Dr. Berejikian's responsibilities include developing NATURES protocols, designing experiments to evaluate the effect of these protocols on postrelease survival, oversight of daily experimental activities, analyzing data, preparing the study finding for publication in annual reports and journal articles.

**Previous research/expertise:** Dr. Berejikian's research as a graduate student dealt with salmonid behavior and predator-prey interactions. He has applied that expertise to NATURES experiments in which he evaluated the consequences of predation training for chinook salmon. In addition, in 1996-1997, he has participated in a large cooperative effort with the Washington Department of Fish and Wildlife (WDFW) to evaluate the relative contributions of different NATURES rearing variables (e.g., cover, structure, substrate) to salmonid survival. Most recently, Dr. Berejikian has initiated experiments into the chemical (pheromone) basis of predator recognition.

Relevant Publications include:

Berejikian, B. A. 1995. The effects of hatchery and wild ancestry and experience on the relative ability of steelhead trout fry (*Oncorhynchus mykiss*) to avoid a benthic predator. Can. J. Fish. Aquat. Sci. 52:2476-2482.

Berejikian, B. A. 1996. Instream postrelease growth and survival of chinook salmon smolts subjected to predator training and alternate feeding strategies. *In* D. J. Maynard, T. A. Flagg, and C. V. W. Mahnken (editors), Development of a natural rearing system to improve supplemental fish quality, 1991 1995, pages 113-127. Report to Bonneville Power Administration, Contract DE-A179-91BP20651. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, Washington 98112.).

Berejikian, B. A., S. B. Mathews, and T. P. Quinn. 1996. Effects of hatchery and wild ancestry and rearing environments on the development of agonistic behavior in steelhead trout fry (*Oncorhynchus mykiss*) fry. Can. J. Fish. Aquat. Sci. 53: 2004-2014.

Berejikian, B. A., E. P. Tezak, S. L. Schroder, C. M. Knudsen, and J. J. Hard. In press. Reproductive behavioral interactions between spawning wild and captively reared coho salmon (Oncorhynchus kisutch). ICES Journal of Marine Science, 00: 000-000.

## Section 10. Information/technology transfer

Information feedback to management decisions will be through annual reports, scientific journal articles, presentations before professional society meetings, presentations at workshops, and frequent discussions with Federal, Tribal, State, PUD, and local fisheries enhancement group fish culture staffs.

## Congratulations!